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RESEARCH MEMORANDUM

EFFECTS ON THE LATERAL OSCILLATION OF FIXING THE RUDDER AND REFLEXING THE FLAPS ON THE BELL X-1 AIRPLANE

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EFFECTS ON THE LATERAL OSCILLATION OF FIXING THE RUDDER AND REFLEXING THE FLAPS ON THE BELL X-1 AIRPLANE

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SUMMARY

Flight tests have been made on the Bell X-1 airplane having the 10-percent-thick wing and the 8-percent-thick tail to evaluate the effects of fixing the rudder and changing the inclination of the principal axes of inertia by reflexing the landing flaps on the snaking which has been encountered over practically the entire range of Mach number and normal-force coefficient. The data were obtained during power-off glides at altitudes between 32,000 and 16,000 feet.

The results showed that fixing the rudder reduced the amplitude of the snaking, but did not eliminate it at a Mach number of 0.84. It was also found that reflexing the flaps to change the inclination of the principal axis of inertia $1\frac{3}{4}^{\circ}$ nose up increased the dynamic lateral stability, but had only a small effect on the snaking oscillation at a Mach number of 0.85.

INTRODUCTION

In flight tests of the Bell X-1 airplane the lateral motion resulting from a large disturbance is initially damped; however, a small constant-amplitude oscillation persists for considerable periods of time. Examples of the oscillation were presented in reference 1 with the computed lateral stability of the airplane. These calculations indicated no tendency toward the neutral oscillation obtained in flight. It was shown, however, that a small, nose-up change in the inclination of the principal axis of inertia should improve the damping of the lateral oscillation. The calculations reported in reference 2 also indicate that a nose-up change of about 2° magnitude would decrease the time required to damp to half amplitude by about 40 percent.

As the first steps in investigating, in flight, the causes for the small-amplitude undamped lateral oscillation it was decided to determine whether rudder motion was a contributing factor and to determine the effects of a small change in the inclination of the principal axis of inertia. The results of these tests are presented in this report.

SYMBOLS

β	angle of sideslip, degrees
M	Mach number
H	pressure altitude, feet
C_{N_A}	normal-force coefficient $\left(\frac{n\frac{W}{S}}{q}\right)$
δ_F	flap deflection, degrees
q	dynamic pressure, pounds per square foot
n	normal acceleration, g units
W	airplane weight, pounds
S	wing area, square feet

DESCRIPTION OF AIRPLANE AND INSTRUMENTATION

The Bell X-1 airplane is a single-place rocket-powered airplane designed for flight research in the transonic-speed range. A photograph of the airplane is shown as figure 1 and a three-view drawing giving the pertinent dimensions is given as figure 2. A complete description of the airplane is given in reference 1.

The wing landing flaps were modified so that they could be reflexed 7° during flight.

The airplane is instrumented to record airspeed, altitude, normal, transverse, and longitudinal accelerations, sideslip angle, wing-flap position, rate of roll, rate of yaw, and elevator, rudder, aileron and stabilizer positions and forces. All records are synchronized by a common timer.

In order to determine if rudder snaking was present, a sensitive control-position transmitter was placed at the rudder. This transmitter was sufficiently sensitive to detect motions as small as 0.05°.

TESTS, RESULTS, AND DISCUSSION

All of the data presented were obtained with the Bell X-1 having the 10-percent-thick wing and the 8-percent-thick horizontal tail. The data were obtained in power-off glides with the propellant tanks empty.

Effect of fixing rudder.- It was felt that, even though the snaking was present at Mach numbers near 1 where the rudder has lost most of its effectiveness, at lower Mach numbers where the rudder is effective the snaking might be produced by small rudder motions. Figure 3 presents time histories of the Bell X-1 snaking at a Mach number of 0.84 at altitudes between 28,000 and 25,000 feet. Time history (a) is of a flight in which the pilot made no effort to hold the rudder fixed. The amplitude of the snaking oscillation is about $1\frac{1}{2}^{\circ}$ in sideslip and the period has a length of about 1.3 seconds. The rudder is moving during the oscillation with a total amplitude of about $\frac{1}{4}^{\circ}$. The direction of the rudder motion is such that, as the airplane sideslips left, the rudder moves to the right. The rudder motion appears to lag the sideslipping very slightly. Part (b) of figure 3 shows a time history of the snaking motions which was obtained while the pilot was holding the rudder pedals fixed. No rudder motion is apparent during this record and the snaking is still present. The amplitude of the snaking appears to be reduced and the length of the period slightly increased. This slight improvement indicates that the rudder may contribute to the snaking; however, the improvement is so slight that it is concluded that rudder snaking is not the primary cause of the oscillation.

Effect of reflexing flaps.- In order to determine the effects of a small change of the angle of inclination of the principal axis of inertia the wing flaps were reflexed 7°. This amount of reflex was estimated to produce a nose-up change of about $1\frac{3}{4}^{\circ}$ in the inclination of the principal axis. The effects of this flap reflex on the damping of the lateral oscillation resulting from a rudder disturbance are shown in figure 4. Records were taken in glides at Mach numbers of about 0.7 to 0.85 with the flaps neutral and reflexed. In the maneuvers made at $M \approx 0.7$, figures 4(a) and 4(b), the pilot attempted to hold the rudder fixed during the oscillations following the abrupt rudder kicks while for maneuvers made at $M \approx 0.85$, figures 4(c) and 4(d), the rudder was released after being neutralized following the rudder kicks. To show more clearly the damping of these records the double amplitude is presented plotted against time on semilogarithmic coordinates in figure 5. In this figure the curves have been arbitrarily placed on the time scale to avoid confusion. This figure shows that reflexing the flaps decreased the time required to damp to half amplitude by about 20 percent at $M \approx 0.7$ and about 50 percent at $M \approx 0.85$. The change in altitude between runs at the same Mach number accounts for part of this increase in stability, but the increase from the change in altitude should be less than 5 percent at $M \approx 0.7$ and 20 percent at $M \approx 0.85$.

Records of the snaking oscillation with flaps neutral and reflexed 7° with the rudder fixed at a Mach number of 0.85 and between 28,000 and 25,000 feet pressure altitude are presented in figure 6. These records show a slight improvement in the oscillation as indicated by the reduction in its amplitude and the irregularity of the motion. The improvement is about the same magnitude as was effected by fixing the rudder. The motion was not eliminated, however, and, although the amplitude is less, the oscillation was still bothersome to the pilot.

CONCLUDING REMARKS

From flight tests of the Bell X-1 airplane having the 10-percent-thick wing and the 8-percent-thick tail the following conclusions may be drawn:

1. Fixing the rudder effected a reduction in amplitude of the snaking oscillation but did not eliminate it in glides at a Mach number of 0.84.

2. Reflexing the flaps to change the inclination of the principal axis in a nose-up direction increased the dynamic lateral stability of the airplane and reduced the amplitude but did not eliminate the snaking oscillation in glides at a Mach number of 0.85.

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REFERENCES

1. Drake, Hubert M., and Wall, Helen L.: Preliminary Theoretical and Flight Investigation of the Lateral Oscillation of the X-1 Airplane. NACA RM L9F07, 1949.

2. Polhamus, Edward C.: A Study of the Dynamic Stability of the Bell X-1 Research Airplane. NACA RM L9K04a, 1950.

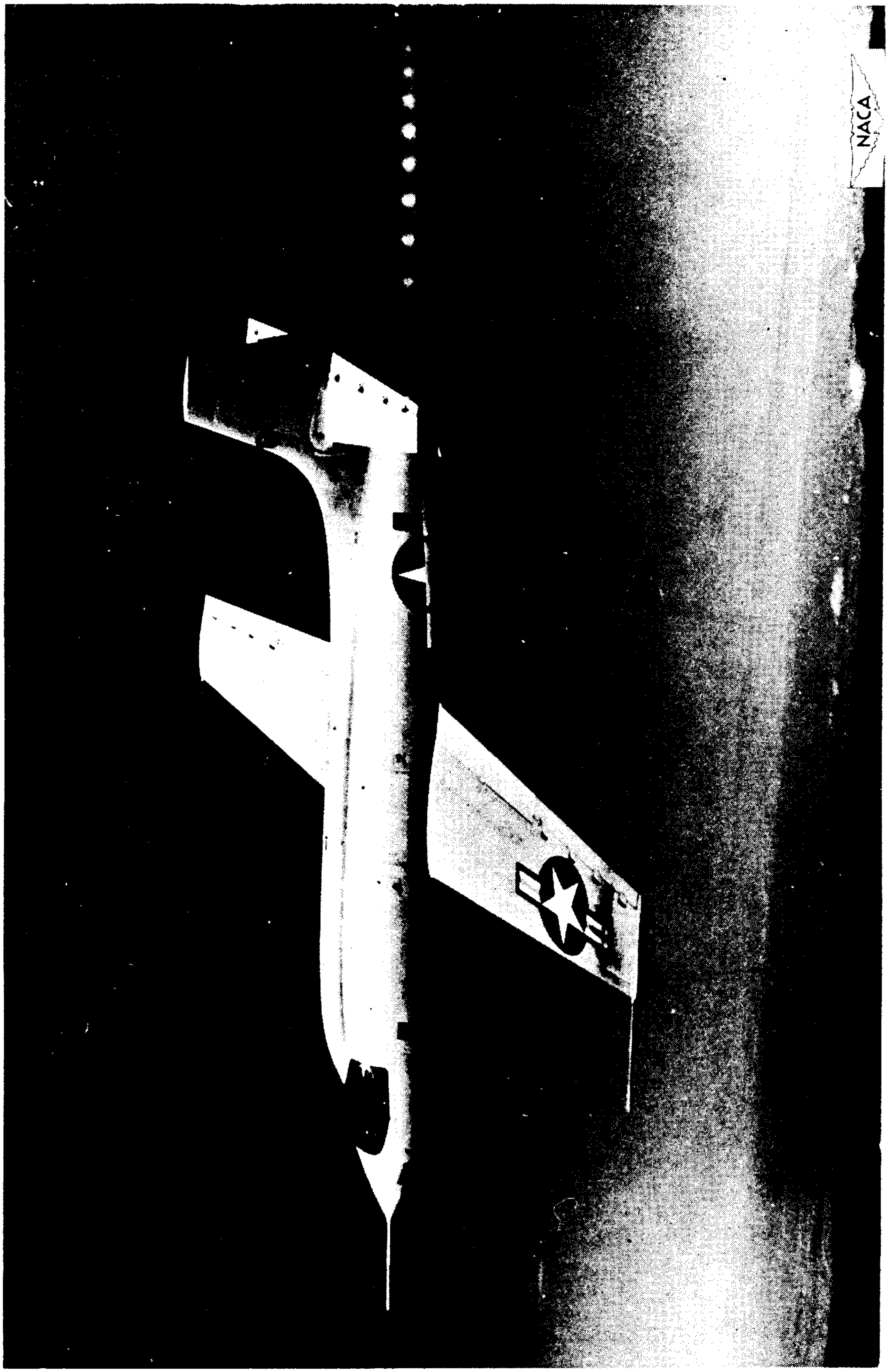


Figure 1.- Photograph of the X-1 airplane in flight.

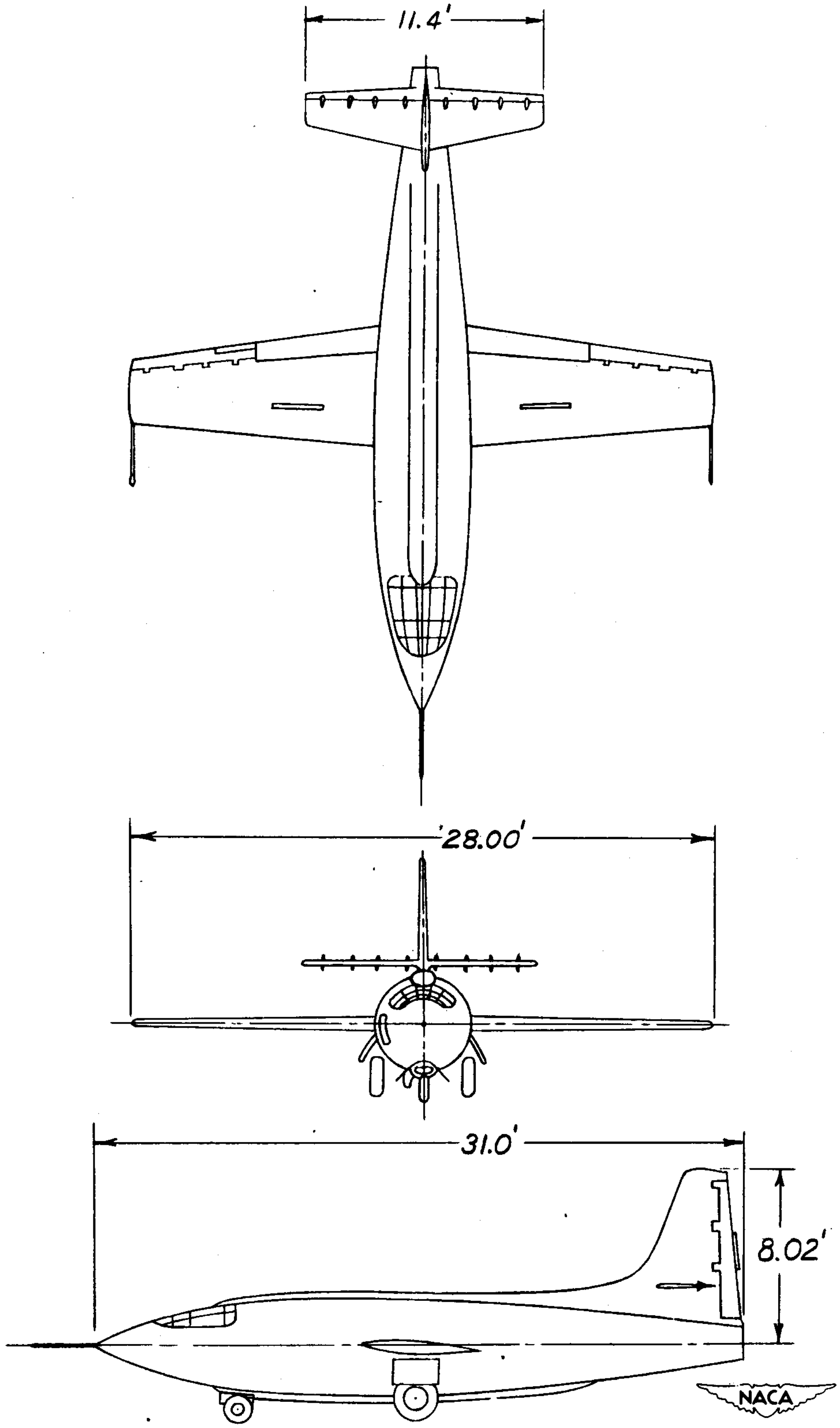
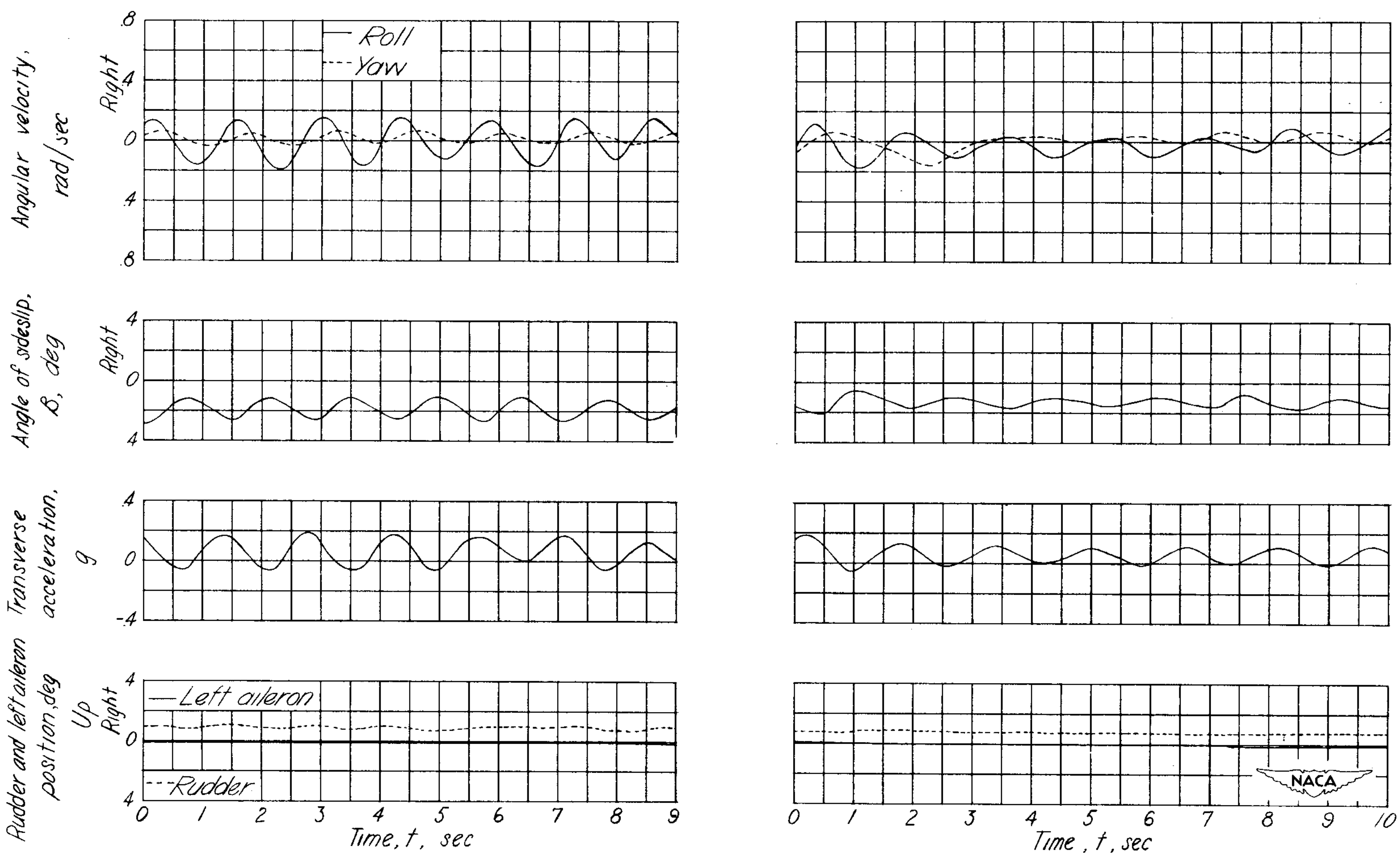


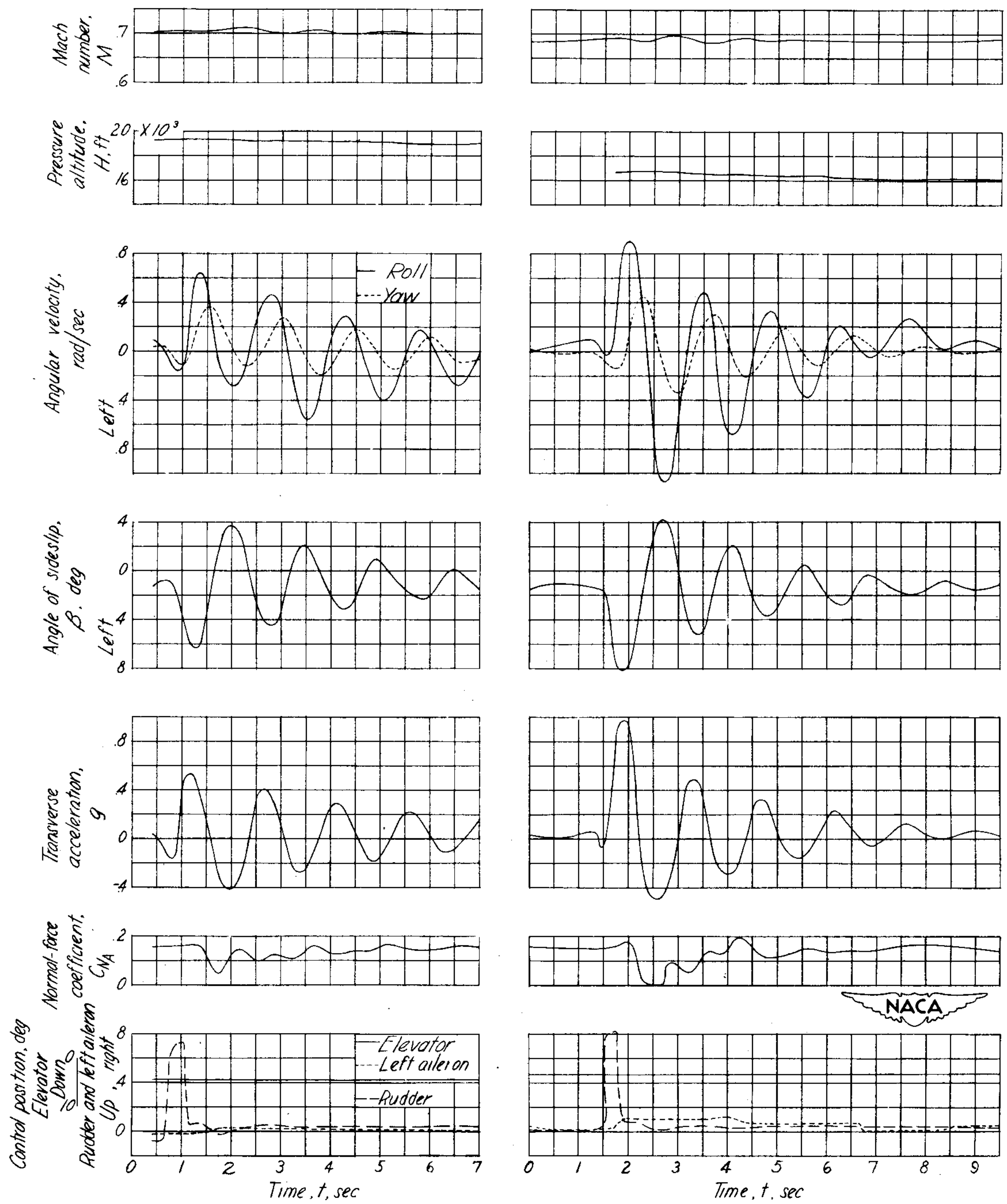
Figure 2.- Three-view drawing of the X-1 airplane.



(a) Rudder free.

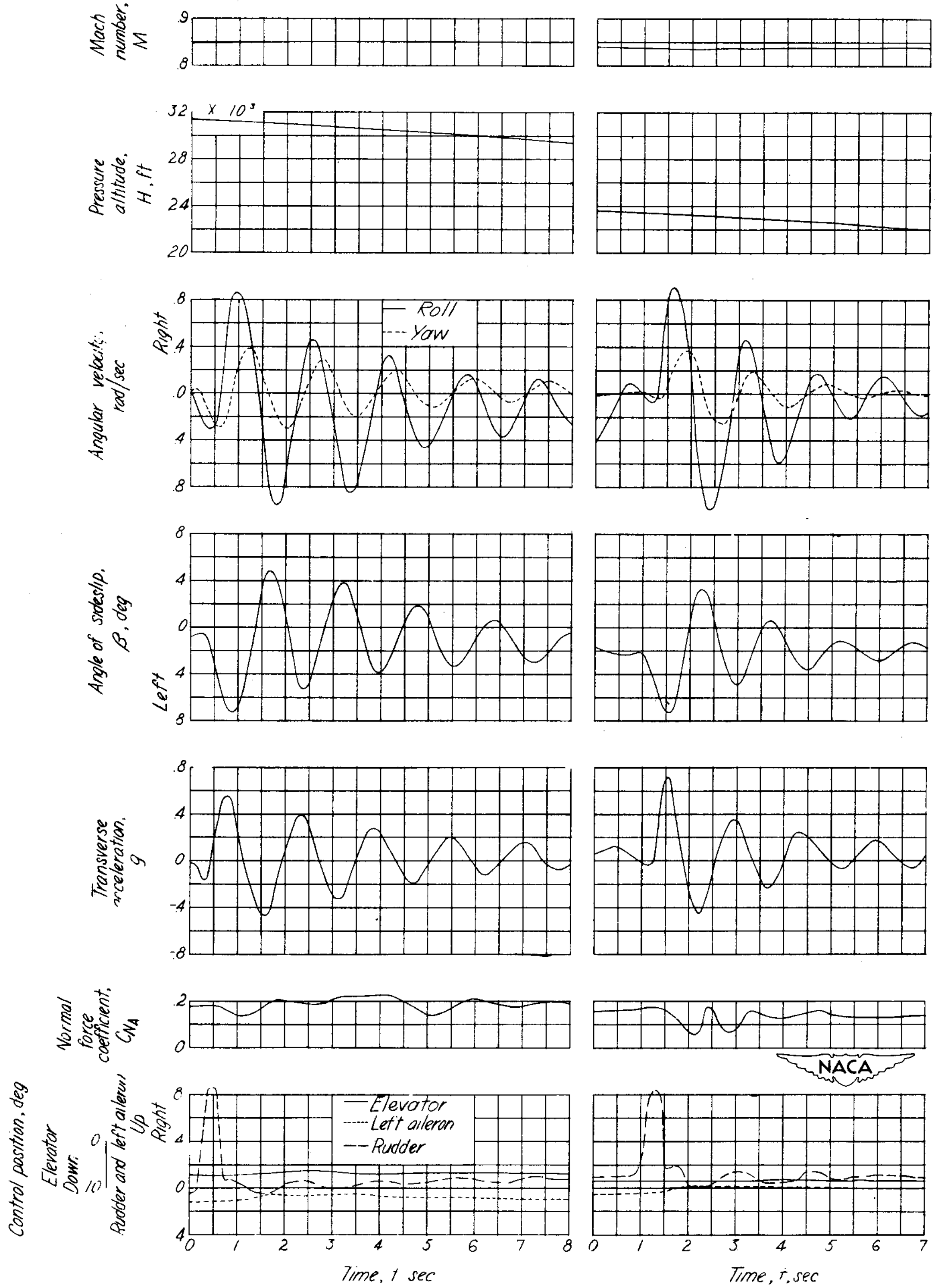
(b) Rudder fixed.

Figure 3.- Time histories of snaking oscillation of Bell X-1 airplane showing effect of fixing the rudder; Mach number, 0.84; pressure altitude 28,000 feet to 25,000 feet; $C_{N_A} = 0.19$.



(a) M ≈ 0.7; flaps 0°. (b) M ≈ 0.7; flaps -7°.

Figure 4.- Effect of reflexing wing flaps on damping of lateral oscillation of Bell X-1 airplane.



(c) M ≈ 0.85; flaps 0°. (d) M ≈ 0.85; flaps -7°.

Figure 4.- Concluded.

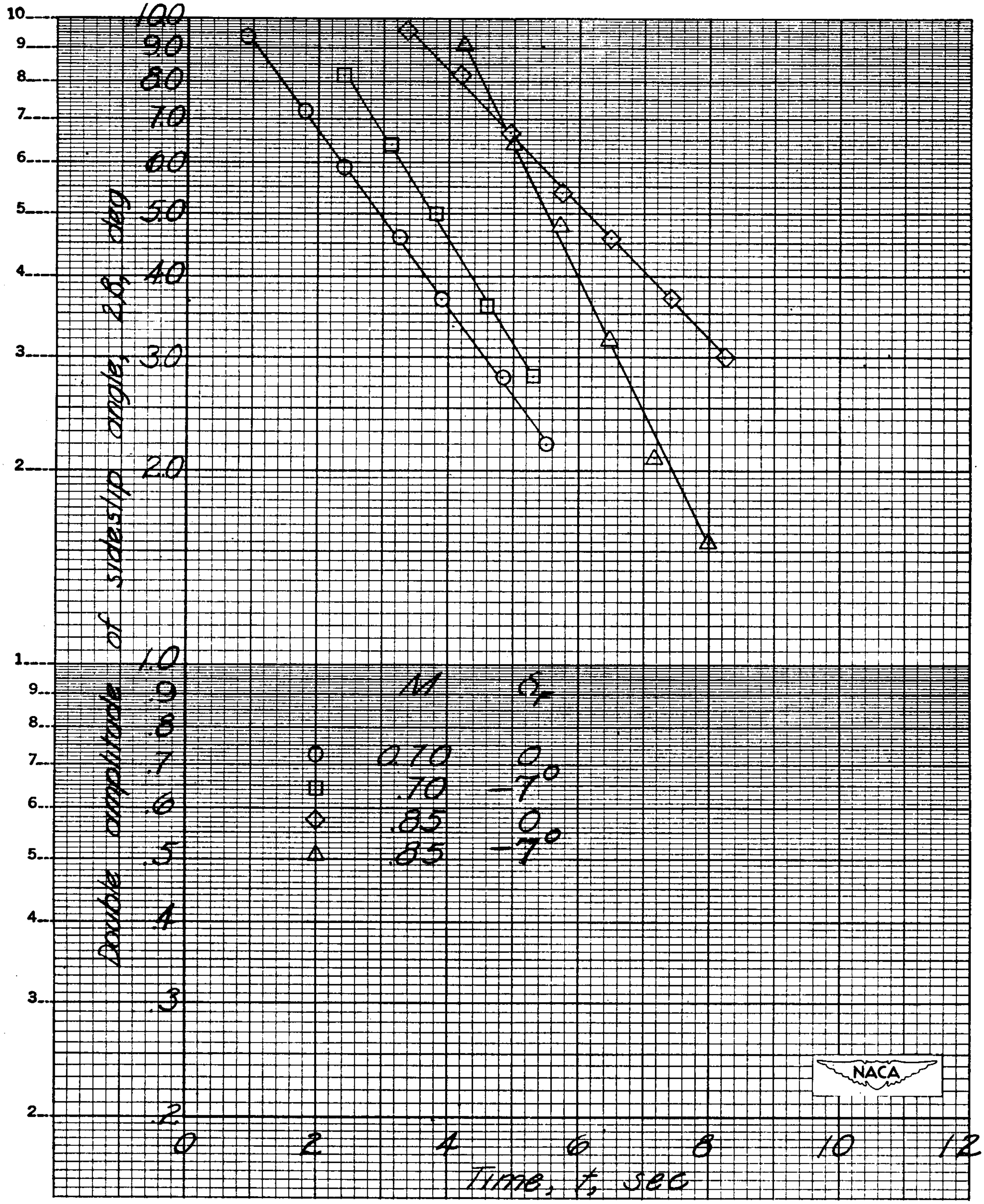
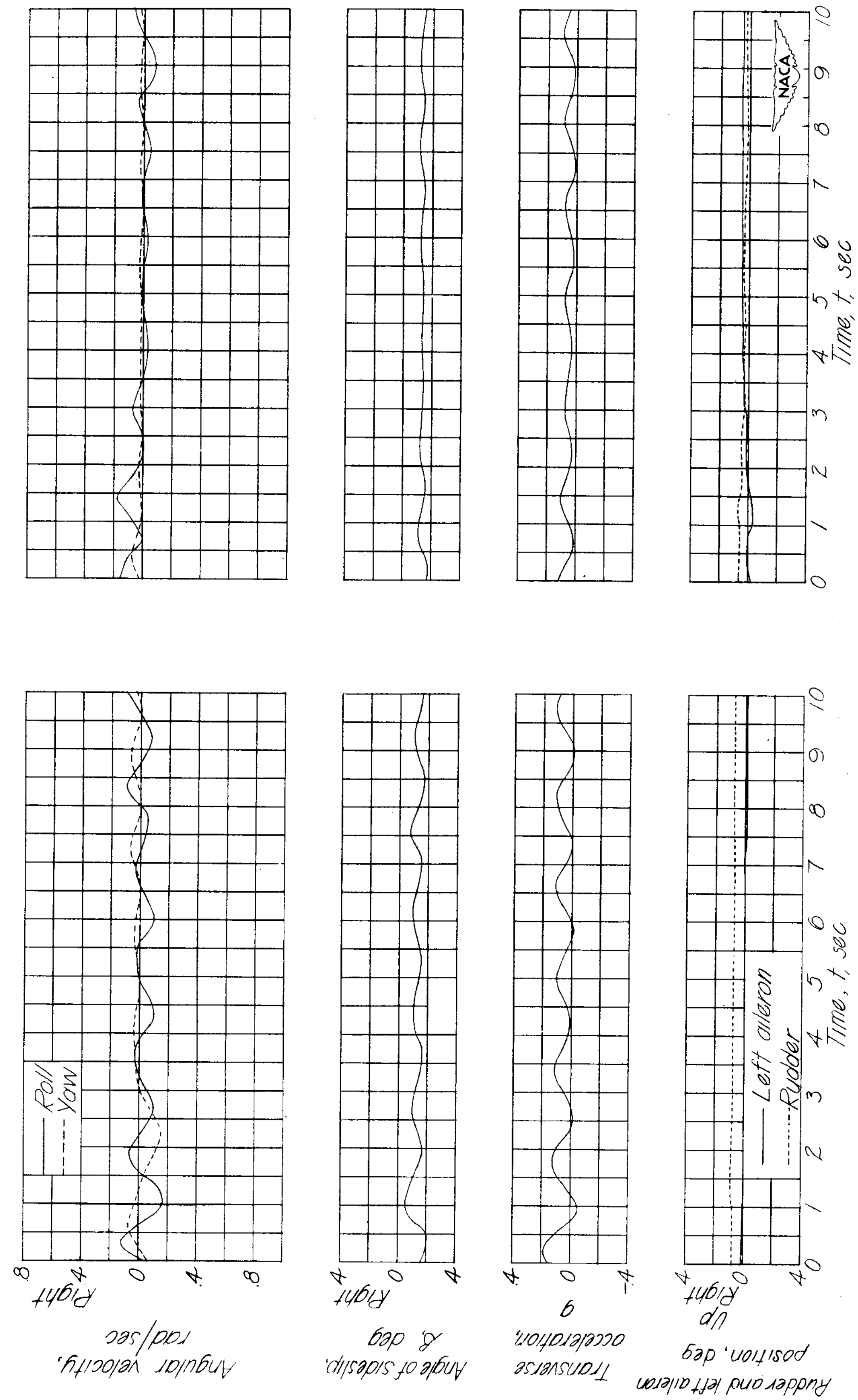


Figure 5.- Variation of double amplitude of sideslip angle with time for Bell X-1 airplane.



(a) Flaps 0°.

(b) Flaps -7°.

Figure 6.- Effect of reflexing wing flaps on snaking oscillation of Bell X-1 airplane; rudder fixed; M = 0.85; pressure altitude 28,000 feet to 26,000 feet; $C_{N_A} = 0.19$.

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